

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
5 April 2001 (05.04.2001)

PCT

(10) International Publication Number
WO 01/24454 A1

(51) International Patent Classification⁷: **H04L 12/28**

(21) International Application Number: **PCT/US00/26804**

(22) International Filing Date:
29 September 2000 (29.09.2000)

(25) Filing Language: **English**

(26) Publication Language: **English**

(30) Priority Data:
09/408,725 29 September 1999 (29.09.1999) **US**

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(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

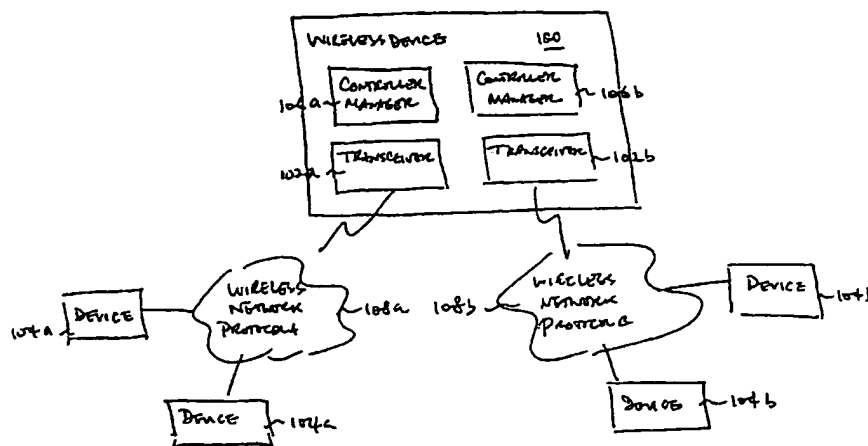
(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

- With international search report.
- Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

[Continued on next page]

(54) Title: **A WIRELESS APPARATUS HAVING MULTIPLE COORDINATED TRANSCEIVERS FOR MULTIPLE WIRELESS COMMUNICATION PROTOCOLS**



(57) Abstract: A wireless device is provided with a first and a second wireless transceivers to transmit and receive signals wirelessly in accordance with a first and a second protocol respectively. The wireless device is further provided with a first and a second controller managers to control, in a coordinated manner, the transmit and receive operations of the first and second wireless transmitters. In various embodiments, the wireless device is further provided with at least one time sharing state machine to facilitate the coordinated control of the wireless transceivers. In some of these embodiments, the wireless device is further provided with a workload monitor to cooperate with the at least one time sharing machine to enable the coordinated control be adaptively performed, based at least in part on transmit and receive workloads of the two protocols. In various embodiments, the protocols may be selected pairs of Bluetooth, 802.11 FH, 802.11 D, 802.11 High Data Rate, Home RF and the like. The wireless device may also be used as a master device or a gateway device of two wireless networks.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A Wireless Apparatus Having Multiple Coordinated Transceivers
For Multiple Wireless Communication Protocols

BACKGROUND OF THE INVENTION

1. **Field of the Invention**

The present invention relates to the field of wireless communication. More specifically, the present invention relates to the problem of concurrent wireless communication with multiple communication partners of different wireless communication protocols.

2. **Background Information**

Advances in microprocessor and communication technology have led to the increase in popularity of wireless communication. Once confined to the privileged, wireless voice communication have become affordable and available to the masses. Today, various efforts are under way to apply wireless communication to replace attachment cables used for attaching peripheral devices, such as printers, scanners and the like, as well as networking cables used for connecting clients, servers and the like. A leading candidate to accomplish the former is commonly known to those skilled in the art as the Bluetooth technology or Bluetooth protocol. Examples of technology to accomplish the latter include the different variants of the IEEE 802.11 Standard published by the Institute of Electrical and Electronic Engineers, 802.11 FH, 802.11 D, 802.11 High Data Rate, as well as Home RF, also known as SWAP to those skilled in the art (*Ephi, what does SWAP stands for?*).

A need has emerged in a number of applications that it is desirable for a device to be able to operate "concurrently" in multiple wireless protocols. One such application is having a notebook computer being able to communicate with peripheral devices such as a phone, a printer, a scanner and the like, in accordance with the Bluetooth protocol; and with other computing devices, such as other peer computers or servers, communication devices, such as modems or adapters, and

networking devices, such as gateways, routers, switches and the like, in accordance with one of the 802.11 protocols or Home RF.

However, the need cannot be met by simply providing the device with multiple transmitters, one for each protocol. The reason is because if multiple ones of these transmitters were to transmit at the same time. The transmitters are going to interfere with each other, resulting in corruption and/or loss of data, as well as degradation in performance.

As will be described in more detail below, the present invention substantially address this need in a very efficient and low cost manner. This and other advantages of the present invention will be readily apparent from the description to follow.

SUMMARY OF THE INVENTION

A wireless device is provided with a first and a second wireless transceivers to transmit and receive signals wirelessly in accordance with a first and a second protocol respectively. The wireless device is further provided with a first and a second controller managers to control, in a coordinated manner, the transmit and receive operations of the first and second wireless transmitters.

In various embodiments, the wireless device is further provided with at least one time sharing state machine to facilitate the coordinated control of the wireless transceivers. In some of these embodiments, the wireless dvice is further provided with a workload monitor to cooperate with the at least one time sharing machine to facilitate the coordinated control be adaptively performed, based at least in part on transmit and receive workloads of the two protocols.

In various embodiments, the protocols may be selected pairs of Bluetooth, 802.11 FH, 802.11 D, 802.11 High Data Rate, Home RF and the like. The wireless device may also be used as a master device or a gateway device of two wireless networks.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

Figure 1 illustrates the wireless device with multiple coordinated transceivers of the present invention, in accordance with one embodiment;

Figures 2a-2b illustrate the relevant operational flow of the instruction blocks in accordance with one embodiment; and

Figure 3 illustrates the relevant operational flow of one of the instruction blocks in accordance with another embodiment.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well known features are omitted or simplified in order not to obscure the present invention.

Parts of the description will be presented using software terminology commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. As well understood by those skilled in the art, these software quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of a digital system; and the term digital system includes general purpose as well as special purpose processors, systems, and the like, that are standalone, adjunct or embedded.

Various operations will be described as multiple discrete steps performed in turn in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent, in particular, the order the steps are presented. Furthermore, the phrase "in one embodiment" will be used repeatedly, however the phrase does not necessarily refer to the same embodiment, although it may.

Referring now to **Figure 1**, wherein an overview of the present invention is shown. As illustrated, wireless device **100** is provided with wireless transceivers **102a** and **102b** to transmit and receive signals wirelessly in accordance with a first and a second wireless communication protocol, to enable device **100** to be communicatively coupled to devices **104a** and devices **104b** of wireless networks **108a** and **108b** respectively. Wireless device **100** further include controller managers **106a** and **106b** to control the operation of wireless transceivers **102a** and **102b** respectively. As will be described in more detail below, controller managers **106a** and **106b** control transmits and receives by wireless transceivers **102a** and **102b**, in a coordinated manner, in accordance with the present invention, to allow wireless device **100** to operate with devices **104a** and devices **104b** of wireless network **108a** and **108b** in accordance with the respective wireless communication protocols at the same time.

In one embodiment, controller managers **106a** and **106b** control transmits and receives by wireless transceivers **102a** and **102b** (hereinafter, simply transceivers), in a periodic fashion. More specifically, in this embodiment, controller managers **106a** and **106b** control transceivers **102a** and **102b** to alternate between transmits by one of the two transceivers and receives by both of the two transceivers. **Figure 2** illustrates a period of operation in accordance with this embodiment. As shown, in time period **T1**, for duration **t1**, control manager **106a** controls transceiver **102a** to perform transmit of signals to devices **104a** of wireless network **108a** (hereinafter, simply network) in accordance with the first wireless communication protocol (hereinafter, simply protocol), while control manager **106b** controls transceiver **102b** to neither perform transmit nor receive of signals to and

from devices **104b** of network **108b**. In time period **T3**, for duration **t3**, the reverse is performed. Control manager **106b** controls transceiver **102b** to perform transmit of signals to devices **104b** of network **108b** in accordance with the second protocol, while control manager **106a** controls transceiver **102a** to neither perform transmit nor receive of signals to and from devices **104a** of network **108a**. In time periods **T2** and **T4**, for duration **t2** and **t3** respectively, control managers **106a** and **106b** control both transceivers **102a** and **102b** to perform receive of signals from devices **104a** and **104b** of network **108a** and **108b** in accordance with the respective protocols respectively.

Since all wireless protocols operate on either a carrier sense or contention free protocol, devices **104a** are able to receive in time period **T1**, and transmit when there are packets to transmit, but otherwise receive, in time periods **T2-T4**. Likewise, devices **104b** are able to receive in time period **T3**, and transmit when there are packets to transmit, but otherwise receive, in time periods **T1-T2** and **T4**.

Accordingly, wireless device **100** is able to operate with devices **104a** and **104b** of networks **108a** and **108b** in two wireless protocols at the same time.

Note that time periods **T1-T4** may or may not be equal in duration. That is, numerically **t1-t4** may or may not be equal. As will be described in more detail below, in different variants of this embodiment, duration **t1-t4** of time periods **T1-T4** are dynamically and adaptively set. In particular, in some variants, duration **t1-t4** of time periods **T1-T4** are adaptively set based at least in part of transmit and receive workloads of networks **108a** and **108b**.

Referring back to **Fig. 1**, except for the teachings of the present invention incorporated in wireless device **100** to effectuate the above described coordinated manner of operation of transceivers **102a** and **102b**, transceivers **102a** and **102b** as well as controller managers **106a** and **106b** are otherwise intended to represent a broad range of these elements known in the art. Accordingly, except for the teachings of the present invention, which will be further described below, transceivers **102a** and **102b** and controller managers **106a** and **106b** will not be otherwise further described.

Wireless device **100** is intended to represent a wide range of devices that can benefit from having the ability to wirelessly operate with other wireless devices in two or more wireless communication protocols at the same time. Examples of device **100** include but not limited to computers of various form factors, such as desktop, notebook, palm size and so forth, controller devices (i.e. master devices) to manage and control the operation of networks **108a** and **108b**, and gateway devices to facilitate communication between devices **104a** and devices **104b**.

Likewise, devices **104a** and **104b** are intended to represent a broad range of devices that can benefit from being able to communicate wirelessly. Examples of devices **104a** include but not limited to phones, video cameras, speakers, modems, printers and scanners equipped to wireless communicate in accordance with the Bluetooth protocol. Examples of devices **104b** include clients and servers, as well as gateways, modems, hubs, routers, and switches equipped to wireless communicate in accordance with a selected variant of the IEEE 802.11 protocols or Home RF.

For ease of understanding, only two groups of devices **104a** and **104b**, communicating in accordance with the first and second wireless communication protocols are shown in Fig. 1. However, from the description to follow, it will be readily apparent to those skilled in the art, the present invention may be practiced with more than two transceivers (as long as the transceivers are likewise coordinated).

Referring now to Figures 3 and 4, wherein a block diagram and a state diagram illustrating wireless device **100** of Fig. 1 in further detail, in accordance with one embodiment, are shown. As illustrated, each controller manager **106a/106b** of wireless device **100** is endowed with a state machine **300a/300b** to complementarily assist the controller manager **106a/106b** to control its transceiver **102a/102b** in the above described coordinated manner. More specifically, each state machine **300a/300b**, in addition to idle state **410**, has four operating states **412-418** (TX, RX1, NOP, and RX2) to output a signal **304a/304b** denoting a selected one of a

transmit (TX) operation, a receive (RX) operation and no-op (NOP) for its controller manager **106a/106b**.

Upon power-on or reset, each state machine **300a/300b** either transitions from idle state **410** to TX state **412** or NOP state **416**, depending on the state of configuration (config) signal **302a/302b**. One state machine, e.g. **300a**, is configured to transition from idle state **410** to TX state **412**, while the other state machine, e.g. **300b**, is configured to transition from idle state **410** to TX state **412**. Config signal **302a/302b** may be set e.g. via a jumper or other equivalent means, as well as through software.

While in TX state **412**, state machine **300a/300b** remains in the state for duration **ts1**, outputting signal **304a/304b** denoting TX operation for its controller manager **106a/106b**. In one embodiment, where **t1** and **t3** may take on different values, one state machine, e.g. **300a**, is configured with **ts1** set to **t1**, while the other state machine, e.g. **300b**, is configured with **ts1** set to **t3**. **Ts1** may be selectively set in any one of a number of techniques known in the art, e.g. through separate registers or multiplexing circuitry. Upon expiration of **ts1**, state machine **300a/300b** transitions from TX state **412** to RX1 state **414**.

While in RX1 state **414**, state machine **300a/300b** remains in the state for duration **ts2**, outputting signal **304a/304b** denoting RX operation for its controller manager **106a/106b**. In one embodiment, where **t2** and **t4** may take on different values, one state machine, e.g. **300a**, is configured with **ts2** set to **t2**, while the other state machine, e.g. **300b**, is configured with **ts2** set to **t4**. **Ts2** may likewise be selectively set in any one of a number of techniques known in the art. Upon expiration of **ts2**, state machine **300a/300b** transitions from RX1 state **414** to NOP state **416**.

While in NOP state **416**, state machine **300a/300b** remains in the state for duration **ts3**, outputting signal **304a/304b** denoting NOP for its controller manager **106a/106b**. In one embodiment, where **t1** and **t3** may take on different values, one state machine, e.g. **300a**, is configured with **ts3** set to **t3**, while the other state machine, e.g. **300b**, is configured with **ts3** set to **t1**. **Ts3** may likewise be selectively

set in any one of a number of techniques known in the art. Upon expiration of ts3, state machine **300a/300b** transitions from NOP state **416** to RX2 state **418**.

While in RX2 state **418**, state machine **300a/300b** remains in the state for duration ts4, outputting signal **304a/304b** denoting RX operation for its controller manager **106a/106b**. In one embodiment, where t2 and t4 may take on different values, one state machine, e.g. **300a**, is configured with ts4 set to t4, while the other state machine, e.g. **300b**, is configured with ts4 set to t2. Ts4 may likewise be selectively set in any one of a number of techniques known in the art. Upon expiration of ts4, state machine **300a/300b** transitions from RX2 state **418** to TX state **412**.

From TX state **412**, state machine **300a/300b** continues operation as described earlier.

Referring now to **Figures 5 and 6**, wherein a block diagram and a state diagram illustrating wireless device **100** of **Fig. 1** in further detail, in accordance with another embodiment, are shown. As illustrated, for this embodiment, instead of having each controller manager **106a/106b** of wireless device **100** be endowed with a state machine to complementarily assist the controller manager **106a/106b** to control its transceiver **102a/102b** in the above described coordinated manner, wireless device **100** is endowed with a single state machine **500** to assist both controller managers **106a** and **106b**. Similarly, state machine **500**, in addition to idle state **610**, has four operating states **612-618** (S1 – S4) to output a pair of signals **504a-504b** denoting a selected combination of operations, TX with NOP, both RX, and NOP with TX for controller managers **106a** and **106b**.

Upon power-on or reset, state machine **500** transitions from idle state **610** to S1 state **612**. While in S1 state **612**, state machine **500** remains in the state for duration ts1, outputting signal **504a-504b** denoting TX and NOP for controller managers **106a** and **106b**. Ts1 is set to t1. Upon expiration of ts1, state machine **500** transitions from S1 state **612** to S2 state **614**. While in S2 state **614**, state machine **500** remains in the state for duration ts2, outputting signal **504a-504b**

denoting RX for both controller managers **106a** and **106b**. Ts2 is set to t2. Upon expiration of ts2, state machine **500** transitions from S2 state **614** to S3 state **616**.

While in S3 state **616**, state machine **500** remains in the state for duration ts3, outputting signal **504a-504b** denoting NOP and TX for controller managers **106a** and **106b**. Ts3 is set to t3. Upon expiration of ts3, state machine **500** transitions from S3 state **616** to S4 state **618**. While in S4 state **618**, state machine **500** remains in the state for duration ts4, outputting signal **504a-504b** denoting RX for both controller managers **106a** and **106b**. Ts4 is set to t4. Upon expiration of ts4, state machine **500** transitions from S4 state **618** to S1 state **612**.

From S1 state **612**, state machine **500** continues operation as described earlier.

Referring now to **Figure 7**, wherein a block diagram illustrating wireless device **100** of **Fig. 1** in further detail, in accordance with yet another embodiment, is shown. As illustrated, for this embodiment, in addition to having wireless device **100** be endowed with a single state machine **700** to assist both controller managers **106a** and **106b** as described earlier (with signals **708a-708a** denoting TX-NOP, RX-RX or NOP-TX), wireless device **100** is further endowed with register **702**, time sharing manager **704**, and workload monitor **706** operatively coupled to each other and state machine **700** as shown. Register **702** stores t1-t4 for state machine **700**. Time sharing manager **704** dynamically adjusts t1-t4 to enable state machine **700** be able to adaptively assist controller managers **106a** and **106b** in controlling transceivers **102a** and **102b**. For the illustrated embodiment, time sharing manager **704** dynamically adjusts t1-t4 based at least in part on transmit and receive workloads of networks **108a** and **108b**. Transmit and receive workloads are monitored by workload monitor **706** and provided to time sharing manager **704**.

Register **702** may be constituted with any storage circuitry known in the art. Time sharing manager **704** and workload monitor **706** may be implemented with any combinatorial logic or in software.

Thus, a wireless device equipped to substantially operate currently with multiple wireless communication protocols has been described. While the present invention has been described in terms of the above illustrated embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of restrictive on the present invention.

CLAIMS

What is claimed is:

1. An apparatus comprising:
a first and a second wireless transceiver to transmit and receive signals in accordance with a first and a second protocol to and from network devices communicatively coupled to the apparatus via a first and a second wireless network respectively; and
a first and a second controller manager coupled to the first and second wireless transceivers to control the first and second wireless transceivers to perform said transmits and receives in a coordinated manner.
2. The apparatus of claim 1, wherein the first and second controllers periodically, in a coordinated manner, control the first wireless transceiver to perform said transmit of signals to network device(s) of said first wireless network, while controlling the second wireless transceiver to neither perform said transmit nor said receive of signals to and from network device(s) of said second wireless network.
3. The apparatus of claim 2, wherein the first and second controllers further periodically, in a coordinated manner, control the second wireless transceiver to perform said transmit of signals to network device(s) of said second wireless network, while controlling the first wireless transceiver to neither perform said transmit nor said receive of signals to and from network device(s) of said first wireless network.
4. The apparatus of claim 1, wherein the first and second controllers periodically, in a coordinated manner, control both the first and second wireless transceivers to perform said receive of signals from network devices of said first as well as said second wireless networks in accordance with said first and second protocols respectively.

5. The apparatus of claim 1, wherein the first and second controller managers control the first and second wireless transceivers to perform said transmits and receives in a coordinated manner, in accordance with a time sharing schedule.
6. The apparatus of claim 5, wherein the first and second controller managers include a first and a second time sharing state machine respectively, with the first and second state machine complementarily configured to cause the first and second controller managers to control the first and second transceivers in complementary transmit, receive and suspend states, in accordance with the time sharing schedule.
7. The apparatus of claim 5, wherein the apparatus further comprises a timing sharing state machine coupled to the first and second controller managers to cause the first and second controller managers to control the first and second transceivers in complementary transmit, receive and suspend states, in accordance with the time sharing schedule.
8. The apparatus of claim 7, wherein the apparatus further comprises a time sharing manager to adaptively manage the time sharing schedule.
9. The apparatus of claim 8, wherein the time sharing manager adaptively manages the time sharing schedule based at least in part on transmit or receive workloads of said first and second wireless networks.
10. The apparatus of claim 9, wherein the apparatus further includes a workload monitor to track transmit or receive workloads of said first and second wireless networks.
11. The apparatus of claim 1, wherein the first and the second protocol are two protocols selected from a group consisting of Bluetooth, 802.11 FH, 802.11 D, 802.11 High Data Rate, and Home RF.

12. The apparatus of claim 1, wherein the apparatus is a computer having a form factor selected from a group consisting of a desktop type, a notebook type and a palm size type.

13. In an apparatus having a first and a second wireless transceiver; a method of operation comprising:

(a) periodically operating the first wireless transceiver to perform transmit of signals to network device(s) of a first wireless network in accordance with a first protocol, while controlling the second wireless transceiver to neither perform transmit nor receive of signals to and from network device(s) of a second wireless network in accordance with a second protocol; and

(b) periodically operating the second wireless transceiver to perform transmit of signals to network device(s) of said second wireless network in accordance with said second protocol, while controlling the first wireless transceiver to neither perform transmit nor receive of signals to and from network device(s) of said first wireless network in accordance with said first protocol.

14. The method of claim 13, wherein the method further comprises (c) periodically operating the first and second wireless transceivers to perform receive of signals from network device(s) of said first as well as second wireless networks in accordance with said first and second protocols respectively.

15. The method of claim 13, wherein the method further comprises (c) adjusting performance periodicity of (a) and (b).

16. The method of claim 15, wherein (c) is performed adaptively based at least in part on transmit or receive workloads of the first and second networks.

17. A collection of apparatuses comprising:

a first apparatus equipped to communicate wirelessly in accordance with a first protocol;

a second apparatus equipped to communicate wirelessly in accordance with a second protocol; and

a third apparatus equipped to communicate wirelessly with said first and apparatuses in accordance with said first and second protocols respectively, as well as equipped to automatically coordinate transmit and receive operations conducted in accordance with said two protocols to enable the third device to operate with said first and second apparatus at the same time.

18. The collection of apparatuses of claim 17, wherein the third apparatus is further equipped to perform said automatic coordination of transmit and receive operations conducted in accordance with said two protocols in an adaptive manner, based at least in part on transmit or receive workloads of the two protocols.

19. A collection of networked apparatuses comprising:

a first plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a first protocol;

a second plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a second protocol; and

a master apparatus equipped to communicate wirelessly with said first and second plurality of apparatuses in accordance with said first and second protocols respectively, as well as equipped to automatically coordinate transmit and receive operations conducted in accordance with said two protocols to enable the master device to manage and control said first and second plurality of apparatuses at the same time.

20. A collection of networked apparatuses comprising:

a first plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a first protocol;

a second plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a second protocol; and

a gateway apparatus equipped to communicate wirelessly with said first and second plurality of apparatuses in accordance with said first and second protocols respectively, as well as equipped to automatically coordinate transmit and receive operations conducted in accordance with said two protocols to enable the gateway apparatus to facilitate communication between said first plurality of apparatuses and said second plurality of apparatuses.

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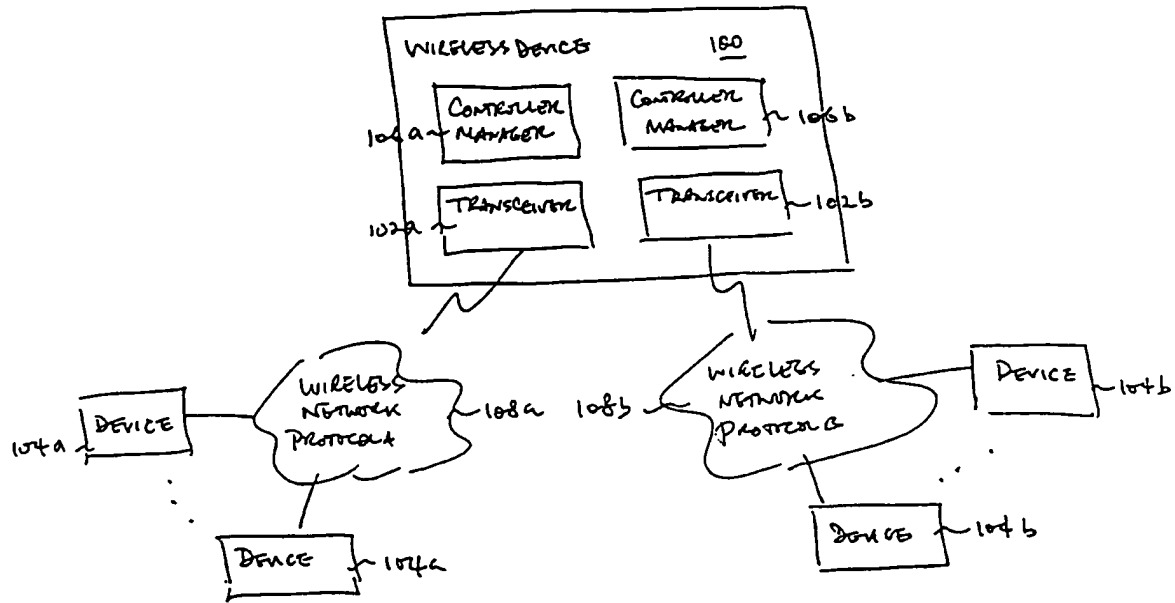


FIG. 1

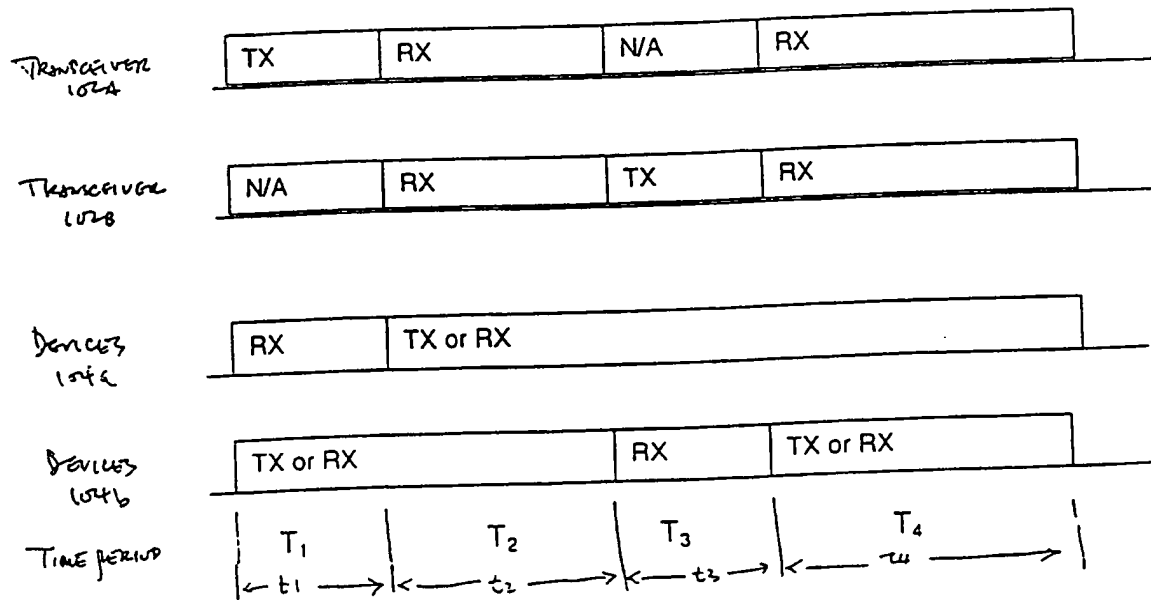


FIG. 2

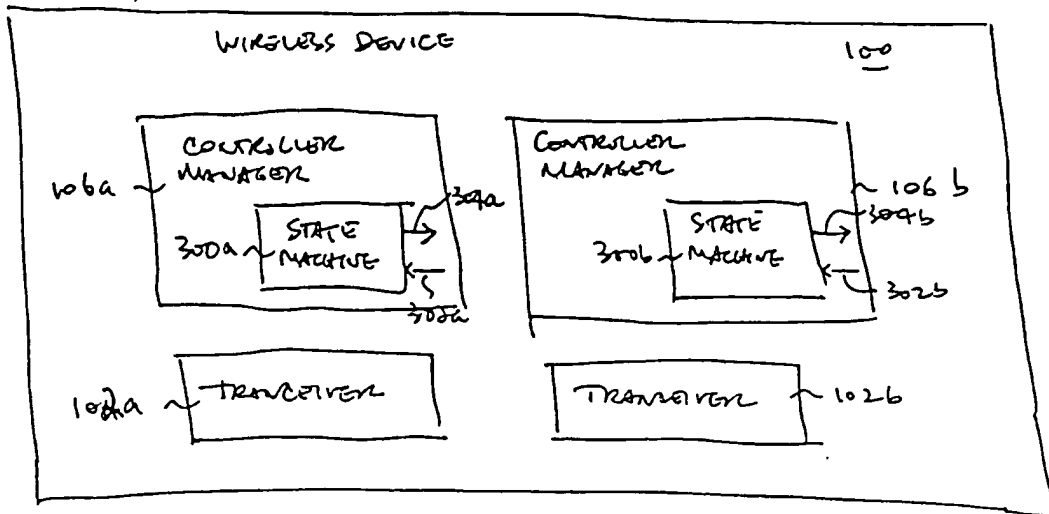


FIG. 3

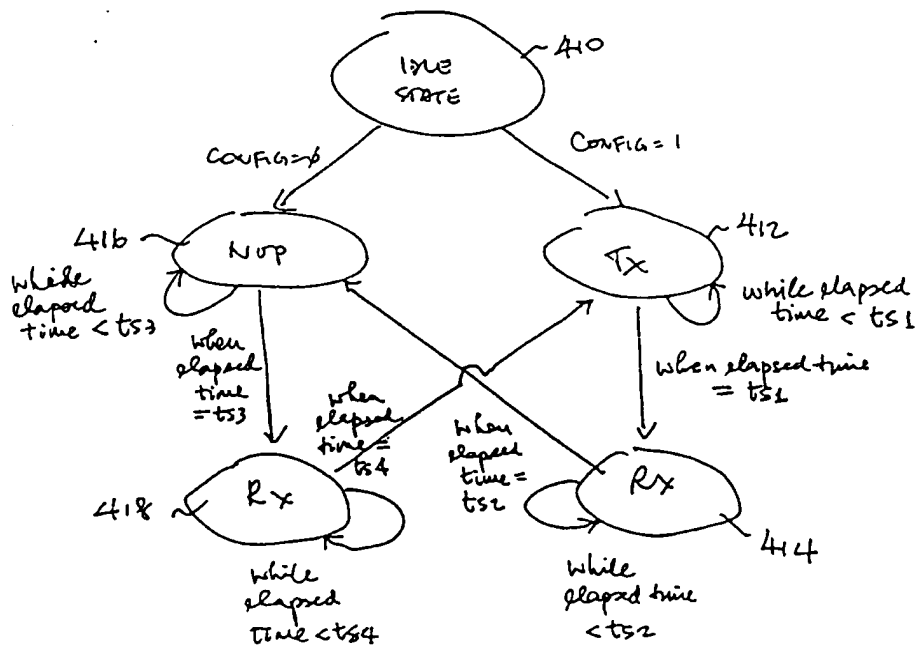


FIG. 4

3/4

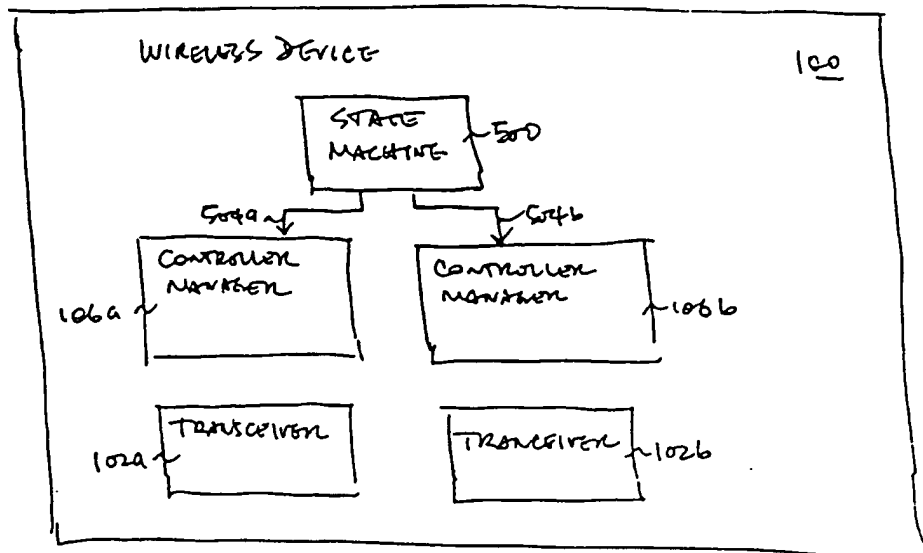


FIG. 5

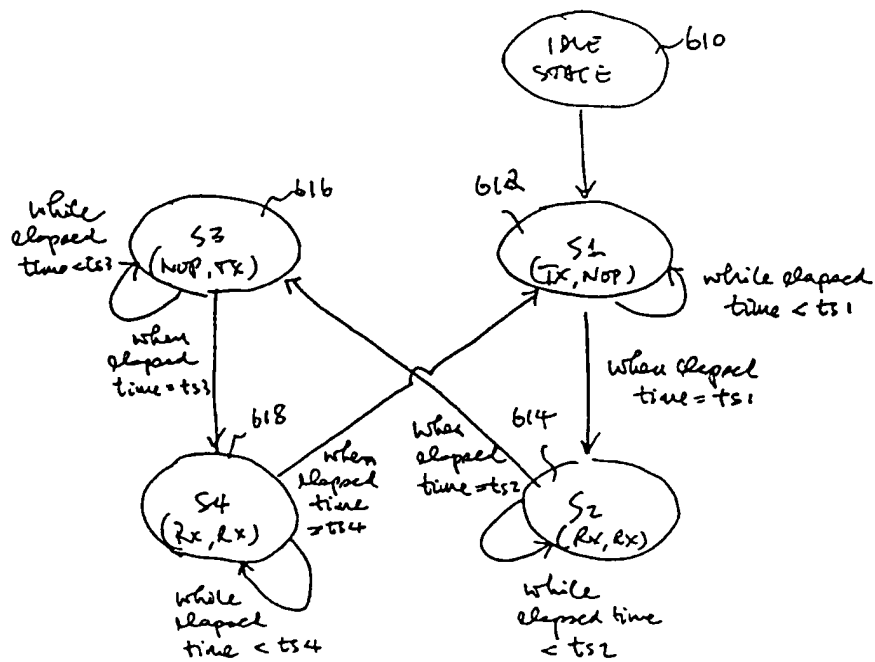


FIG. 6

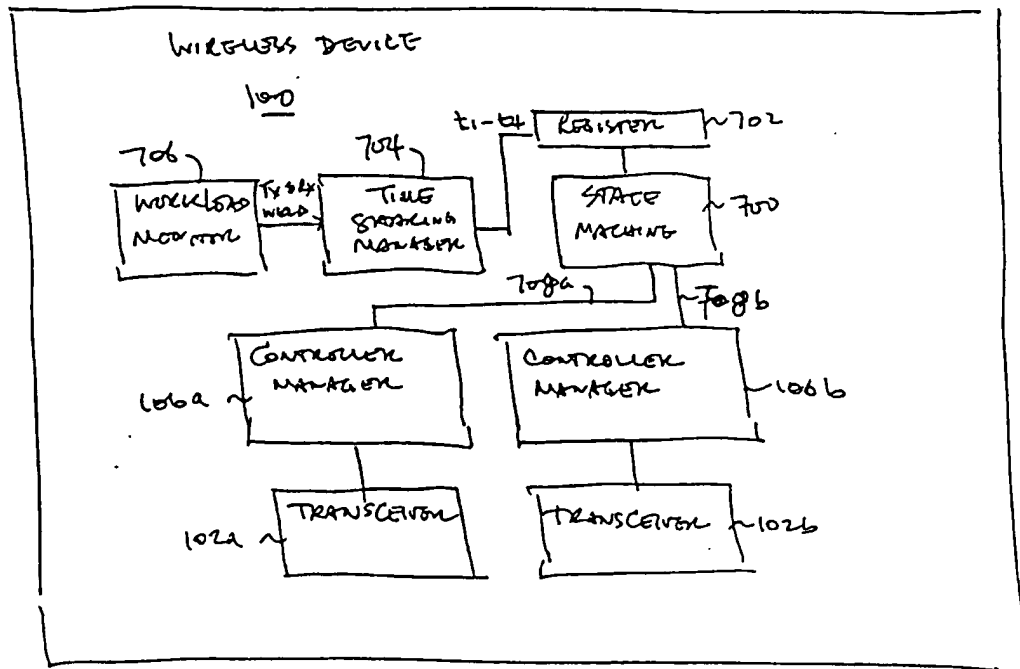


FIG. 7

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/26804

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04L12/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 29126 A (JOERESSEN OLAF J ;NOKIA MOBILE PHONES LTD (FI)) 10 June 1999 (1999-06-10) page 1, line 5 -page 3, line 4 page 8, line 20 -page 13, line 27 figures 4,5,7,8 -----	1-20

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

26 January 2001

Date of mailing of the international search report

06/02/2001

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/26804

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